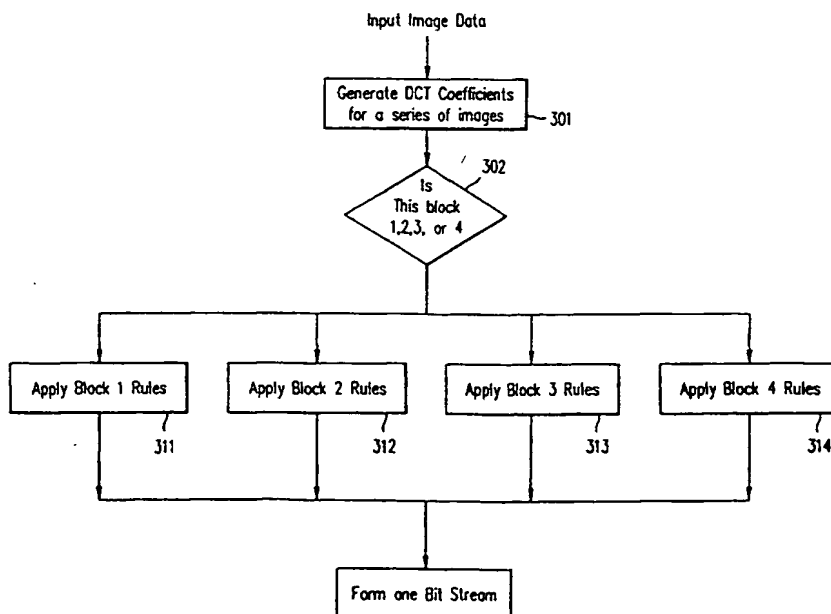




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>6</sup> :</b> <b>G06K 9/36, 9/46</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 99/10837</b> <b>(43) International Publication Date:</b> 4 March 1999 (04.03.99)
<b>(21) International Application Number:</b> PCT/US98/17530 <b>(22) International Filing Date:</b> 24 August 1998 (24.08.98)  <b>(30) Priority Data:</b> 60/056,968           26 August 1997 (26.08.97)   US 09/138,061           21 August 1998 (21.08.98)   US  <b>(71) Applicant:</b> DIGIMARC CORPORATION [US/US]; Suite 500, One Centerpoint Drive, Lake Oswego, OR 97035 (US).  <b>(72) Inventors:</b> RHOADS, Geoffrey, B.; 304 S.W. Tualatin Loop, West Linn, OR 97068 (US). DAVIDSON, Clay; 17374 Lake Haven Drive, Lake Oswego, OR 97035 (US). RO- DRIGUEZ, Anthony; 3104 N.E. 31th Avenue, Portland, OR 97212 (US).  <b>(74) Agent:</b> GALBI, Elmer; 13314 Vermeer Drive, Lake Oswego, OR 97035 (US).		<b>(81) Designated States:</b> AU, CA, FI, JP, MX, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the</i> <i>claims and to be republished in the event of the receipt of</i> <i>amendments.</i>

**(54) Title:** METHOD AND APPARATUS FOR WATERMARKING VIDEO IMAGES



**(57) Abstract**

Embedding a watermark in an image by changing selected DCT coefficients (301) in the blocks and macro blocks of coefficients which represent the image. The changes in the blocks that comprise each macro block are done in a coordinated manner so that the phase of the watermark signal is preserved across the block boundaries. The bit rate of the image signal is preserved by maintaining a count that represents the amount that the bit rate has been increased by changes in coefficients less the amount that the bit rate has been decreased by changes in the coefficients.

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Larvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav	TM	Turkmenistan
BF	Burkina Faso	GR	Greece		Republic of Macedonia	TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's	NZ	New Zealand		
CM	Cameroon		Republic of Korea	PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

1 METHOD AND APPARATUS FOR WATERMARKING VIDEO IMAGES  
23 Field of the Invention:

4 This invention relates to stenography, to copy protection and to applying and  
5 detecting digital watermarks in video images.  
6

7 Background of the invention:

8 The advent of technology for storing images on digital media has increased the  
9 need for a method to protect against piracy. Images stored on prior forms of media  
10 (e.g. VHS, Beta, audiotapes, etc.) are inherently degraded when copied. Images  
11 stored on digitally encoded media can be copied with no degradation; therefore,  
12 perfect copies of copies of copies, etc. can be made.  
13

14 The introduction of Digital Versatile Discs (DVD) containing movies has created  
15 increased incentives for both casual and professional unauthorized copying. At the  
16 movie industry's urging, technology has been put in place to protect against simple  
17 duplication of DVD disks using equipment available to unsophisticated consumers.  
18 This is similar to the protection that exists which prevents one from duplicating a  
19 VCR tape by connecting together two commercially available VCRs.  
20

21 While such protection mechanisms protect against some types of copying, a  
22 personal computer connected to a DVD device present a much more complicated  
23 problem. Open architecture devices such as personal computers reproduce the  
24 signals in the "clear" and such devices have many entry points, which can be used  
25 to duplicate material once it is in the "clear". The present invention uses digital  
26 watermarks to address the above described problem. The present invention also  
27 has other applications

1  
2 It is known that to facilitate the detection of digital watermarks one can insert a  
3 watermark signal that forms a grid. The grid can be used to determine orientation  
4 and scale. With the present invention the data signal and the grid signal are  
5 integrated into a single watermark signal in such a manner that the visual artifacts  
6 introduced by the watermark are minimized.

7  
8 In applications such as DVD, an important factor that needs be considered is the bit  
9 rate of the bit stream. There are disadvantages if introduction of a watermark into a  
10 bit stream changes the bit rate. For example if images are going to be recorded on  
11 a medium such as a DVD disc, increasing the number of bits in the bit stream will  
12 decrease the number of images that can be recorded on a single disk. It is known  
13 that, in general, adding a watermark to a stream of images will increase the number  
14 of bits in the bit stream. The present invention provides a method and apparatus,  
15 which preserves the bit rate even though watermarks are introduced into the  
16 images.

17  
18 Summary of the invention:

19 The well-known JPEG and MPEG data compression techniques transform images  
20 utilizing a discrete cosine transform (DCT) which produces a matrix of DCT  
21 coefficients. These coefficients are arranged into blocks (e.g. into 8 by 8 blocks of  
22 coefficients). The blocks of DCT coefficients are in turn arranged into macro blocks  
23 (e.g. into 16 by 16 arrays containing four 8 by 8 blocks). With the present invention  
24 selected DCT coefficients in each block are slightly increased or slightly decreased  
25 in response to a watermark signal. The changes in the blocks that comprise each  
26 macro block are done in a coordinated manner so that the phase of the watermark  
27 signal is preserved across the block boundaries. By preserving the phase across

1 block boundaries, a detectable grid is formed which can be used as an orientation  
2 and scaling grid.

3  
4 The present invention also maintains the bit rate of the image signal. The bit rate of  
5 the signal is preserved by maintaining a count (referred to as the cumulative change  
6 count) that represents the amount that the bit rate has been increased by changes  
7 in coefficients less the amount that the bit rate has been decreased by changes in  
8 the coefficients. If at any time the cumulative change count exceeds a pre-  
9 established limit, coefficient changes that decrease the cumulative change count  
10 continue; however, coefficient changes that increase the cumulative change count  
11 are suspended. The suspension of coefficient changes that increase the  
12 cumulative change count continues until the cumulative change count falls below  
13 the pre-established limit. The above described process can be described as  
14 selectively changing the intensity of a watermark signal in a bit stream so as to  
15 prevent the entropy of the combined signal from exceeding a pre-established limit.

16 **Brief Description of the Figures:**

17 Figure 1 is a diagram illustrating how the pixels in an image are arranged into blocks  
18 and how the resulting DCT coefficients are numbered.

19  
20 Figure 2 is a diagram, which shows how the blocks of DCT coefficients are arranged  
21 into macro blocks.

22  
23 Figure 3 is a program flow diagram showing how the coefficients in each block of a  
24 macro block are treated so as to preserve the phase of watermark signal in each  
25 macro block.

1 Figure 4 is a program flow diagram showing how the bit rate in the data stream is  
2 maintained constant.

3  
4 Description of preferred embodiments:

5 The well know MPEG (Motion Picture Expert Group) and JPEG (Joint Photographic  
6 Expert Group) image compression techniques use a DCT (Discrete Cosine  
7 Transform) to generate a matrix of coefficients. The preferred embodiment of the  
8 invention shown herein slightly modifies the DCT coefficients (either slightly  
9 increases or slightly decreases the value of the coefficients) so as to embed a  
10 digital watermark in the image. Such a digital watermark can later be detected by  
11 conventional cross correlation techniques.

12  
13 As illustrated in Figure 1, the MPEG and JPEG techniques divide an image into 8 by  
14 8 blocks of pixels. Each block of pixels is then used to generate an eight by eight  
15 block of DCT coefficients. The 8 by 8 blocks of coefficients are divided into "macro  
16 blocks", each of which consist of four of the original blocks. This is illustrated in  
17 Figure 2. The rows and columns of DCT coefficients in each block are numbered  
18 from top to bottom and left to right as illustrated in Figure 1. The first row and the  
19 first column are designated as the "0" row and "0" column.

20  
21 Certain of the DCT coefficients in each block are selected as the coefficients that  
22 will carry a selected bit of the digital watermark signal. In the preferred embodiment  
23 the three coefficients circled in Figure 1 are used to carry the first or "0" bit of the  
24 watermark data signal. These three coefficients are modified, that is, either slightly  
25 increased or slightly decreased depending upon the value of the "0" bit of the  
26 watermark data. In a similar manner other coefficients are slightly changed in order  
27 to carry the other bits of the watermark signal.

1  
2 One aspect of the present invention is directed to insuring that the sinusoids  
3 generated by the changes made to the DCT coefficients are continuous, that is, in-  
4 phase across the four blocks that constitute each macro block. First, if the  
5 sinusoids that carry the watermark are continuous across each macro block, there  
6 will be less edge effects and the watermark will be less visually noticeable. Second,  
7 the sinusoids which are continuous over the four blocks of each macro block create  
8 a low level orientation or grid signal. This low level grid signal can be detected to  
9 determine the orientation and scale of the watermark. The grid signal can then be  
10 detected using the cross correlation techniques. Cross correlation detection  
11 techniques are for example shown in copending patent application 08/649,149 filed  
12 5/16/96 and in issued patent patents 5,748,763 and 5,748,783.

13  
14 If certain DCT coefficients in adjacent blocks are modified in the same direction, the  
15 resulting sinusoids will not be continuous across block boundaries. With the  
16 present invention the changes made to the coefficients of each of the four blocks in  
17 a macro block are coordinated so that the resulting sinusoids will be continuous  
18 across block boundaries within each macro block. The changes are coordinated  
19 using the rules explained below.

20  
21 The blocks in each macro block are numbered as shown in Figure 2. Block one is  
22 considered the base block. The coefficients in this block are changed in a  
23 conventional way by the associated bits of the watermark signal. Note, the  
24 following paragraphs relate to how the coefficients which are circled in Figure 1 are  
25 changed in response to the "0" bit of the watermark. It should be understood that  
26 other coefficients must be similarly changed to carry the other bits in the watermark  
27 data.

1

2 In block 1, the coefficients that are circled in Figure 1 are slightly increased or  
3 slightly decreased in response to the "0" bit of the watermark data. In blocks 2, 3  
4 and 4, the circled coefficients shown in Figure 1 are changed in response to the  
5 zero bit of the watermark according to the following rules.

6 Block 2: invert the direction of the change if the coefficient is in an odd row.

7 Block 3: invert the direction of the change if the coefficient is in an odd  
8 column

9 Block 4: invert the direction of the change if the coefficient is in an odd row  
10 or if it is in an odd column, but do not invert the direction of the  
11 change if the coefficient is in both an odd row and in an odd column.

12

13 If the above rules are followed the sinusoids generated by the change in the DCT  
14 coefficients will be continuous across the boundaries in the four blocks that form  
15 each macro block. These sinusoids will be able to be detected using conventional  
16 cross correlation techniques and they can be used as a grid to determine the scale  
17 and rotation of the image. The data bits in the watermark will also be able to be  
18 detected using conventional watermark detection techniques. Thus, the watermark  
19 data itself is used to form the grid that can be used to determine scale and rotation.

20

21 Figure 3 is an overall program flow diagram of the above described aspect of the  
22 preferred embodiment. The system accepts a stream of data that represents  
23 images. Block 301 is a conventional device or program module that generates DCT  
24 coefficients for the images in the data stream. These coefficients are sent to a  
25 decision unit 302 which separates the data into macro blocks and sends it to units  
26 311, 312, 313 and 314 depending upon whether the data represents a block 1, 2, 3



1 or 4 in a macro block. Units 311-313 modify the DCT coefficients in order to imbed  
2 a watermark signal according to the following rules.

3 Unit 311: modify the coefficients in a conventional manner to imbed  
4 watermark.

5 Unit 312: invert the direction of the change if the coefficient is in an odd row.

6 Unit 313: invert the direction of the change if the coefficient is in an odd  
7 column

8 Unit 314: invert the direction of the change if the coefficient is in an odd row  
9 or if it is in an odd column, but do not invert the direction of the  
10 change if the coefficient is in both an odd row and in an odd column.

11 The output of units 311 to 314 is combined by unit 320 back into a single data  
12 stream. It is noted that each of the units shown in Figure 3 could be separate units,  
13 which are either programmed, or hardwired to perform the specified functions.

14 Alternatively all the function could be performed in a single programmed computer  
15 on a time-shared basis. The unit which generates DCT coefficients is conventional  
16 and such units are known and not part of the present invention.

17

18 The previous discussion describes how a watermark can be introduced in the DCT  
19 domain. It is noted that the durability of the overall watermarking can be increased  
20 by using two watermarks. One watermark can be added by modification of the  
21 pixels in the original image in the manner as described in US patents 5,748,763 or  
22 5,748,783 and then a second watermark can be added by modification of the  
23 coefficients in the DCT domain as described herein.

24

25 Another problem addressed by the present invention is the need to maintain a  
26 constant bit rate in a stream of bits representing a series of images even though  
27 watermarks are added to the images. It is noted that MPEG and JPEG systems use

1 variable length codes to represent data, hence, adding watermarks generally  
2 increases the bit rate of a data stream. Typically a watermark has no correlation with  
3 the image into which the watermark is embedded, thus embedding an image in a  
4 watermark produces an image which has a higher entropy than the original image.  
5 The bit rate of a data stream transmitting an image correlates directly to the entropy  
6 of the image.

7

8 Typically the number of codes used to code an image, that is, the number of entries  
9 in the Huffman table of a coded image, is relatively large (e.g. 500). However, the  
10 changes that occur when a watermark is introduced into an image can be illustrated  
11 with following simple example. Consider a data stream that has only four symbols,  
12 s1, s2, s3 and s4, which are encoded as follows:

13                      Symbol    code

s1	0
S2	01
S3	110
S4	111

14

15    Then consider a data stream as follows:

16            Bit stream:                      0011010111010

17            Decoded stream            0/0/110/10/111/0/10

18            Decoded message:    s1, s2, s3, s2, s4, s1, s2

19

20    When a watermark is added to an image the bits in the image are slightly changed.

21    In the above simplistic illustrative example, in some situation the symbol s2 would  
22    be changed to the symbol s3 and hence the number of bits in a bit stream which  
23    transmits the image would be increased. In fact there are mathematical principles

1 (not explained herein) which show that when a normally distributed watermark (that  
2 is, a watermark with a Gaussian distribution) is added to an image, and the image is  
3 transmitted using variable length Huffman codes, the length of the bit stream will of  
4 necessity be increased.

5  
6 The present invention provides a technique for insuring that when a watermark is  
7 added to a data stream, the bit rate will be maintained constant. It is noted that the  
8 present invention does not violate the above-described mathematical principle,  
9 because with the present invention, some of the redundancy normally used to  
10 watermark images is in certain circumstances decreased. That is in certain  
11 circumstances the intensity of the watermark is decreased.

12  
13 With the present invention, the watermark is modified in response to characteristics  
14 of the image. Thus, to some extent the watermark is correlated to the image into  
15 which the watermark is embedded. In this way a watermark can be embedded into  
16 an image and the entropy of the combined image and watermark will be  
17 substantially equal to the entropy of the watermark alone.

18  
19 With the present invention, the system maintains a cumulative count of the amount  
20 that the coefficients have been changed to any point in time. That is, the amount of  
21 positive changes less the amount of negative changes made since the beginning of  
22 the bit stream is tracked. This amount is herein referred to as the cumulative  
23 change count. If at any time, the cumulative change count exceeds a pre-  
24 established positive limit, no further positive changes are made.

25  
26 Normally it is only necessary to insure that changes do not increase the bit rate  
27 unduly; however, in some instances it may also be desirable to insure that changes

1 do not unduly decrease the bit rate. If this is desired, the same technique as  
2 described above can be used to insure that the cumulative change amount does not  
3 exceed a pre established negative limit. That is, if the cumulative change amount  
4 exceeds a pre-established negative value, positive changes continue in a normal  
5 manner, but no further negative changes are made.

6  
7 The magnitude of the pre-established maximum (and in both a positive and negative  
8 direction) are established at the values which constitutes the change in bit rate  
9 which can be tolerated in a particular system.

10  
11 Figure 4 is a program flow diagram showing how the data rate is maintained  
12 constant notwithstanding the fact that watermarks are added to the images in the  
13 data stream. Block 403A shows that a limit on the amount of positive changes that  
14 can be made to DCT coefficients is established and stored. Block 403C shows  
15 that the cumulative change amount is stored. The cumulative change amount is the  
16 amount of positive changes less the amount of negative changes that have been  
17 made to coefficients since the start of the data stream.

18  
19 The DCT coefficients are calculated in the normal manner as indicated by block  
20 401. Likewise the change in each the DCT coefficients needed to embed the  
21 watermark is also calculated in the normal manner as shown by block 405. Block  
22 405 shows that a check is made to determine if the needed change in a particular  
23 DCT coefficient is positive or negative. Block 409 indicates that if the change is  
24 positive a check is made to determine if the maximum allowable cumulative change  
25 amount stored in block 403A will be exceeded if the change is made.

1 Blocks 415, and 417 indicate that the coefficients will only be changed, if the  
2 change does not cause the cumulative change amount to exceed the limit in 403A.  
3 Finally as indicated by blocks 425 and 427, the cumulative change amount in  
4 register 403C is incremented or decremented if a change to the coefficients is in  
5 fact made. Block 431 indicates that the coefficients are sent to the output of this  
6 process and they are then transmitted and processed in a normal manner.

7  
8 It is noted that the present invention relates to embedding a watermark in an image.  
9 Various know techniques can be used to detect watermarks embedded in images  
10 utilizing the present invention. For example techniques such as those described in  
11 US patents 5,748,763, and 5,748,783 or in the "Communications of the ACM" July  
12 1998/vol. 41, No.7. or in pending US applications serial number 08/746,613 filed  
13 11/12/96 and serial number 08/649,419 which was filed 5/16/98 (all of which are  
14 hereby incorporated herein by reference) could be used.

15  
16 While the process has been described above as one where a change is either made  
17 or not made, it should be understood that alternatively, the amount of the change  
18 could be decreased if the limit in the cumulative change value is being approached.  
19 It is also noted that the system shown in Figure 4 prevents the cumulative change  
20 value from exceeding a pre established positive limit. Since adding a watermark to  
21 an image generally increases the entropy of the image and since Huffman code  
22 tables are normally constructed such that an increase in entropy result in increased  
23 bit rate, the use of only a positive limit is normally appropriate. However, in some  
24 situations, it may be appropriate to tract if the cumulative change amount exceeds a  
25 limit in both the positive and negative directions. Such a check could be added to  
26 Figure 4 prior to block 427.

1

2 It is recognized that by implementing the present invention, the strength of the  
3 watermark is in some cases reduced. However, the reduction is not sufficient to  
4 prevent detection of the watermark. The changes made with the above invention  
5 merely lower the intensity of the watermark in a selective manner, thus in some  
6 instances more processing may be required to detect the watermark.

7

8 In many systems, each Huffman code covers several symbols. In such systems the  
9 calculation indicated by block 405 is not the change in a single symbol that results  
10 from adding a watermark to the image. In such systems the calculation indicated by  
11 block 405 is a calculation of the change that results in the bit string of whatever  
12 combination of symbols used in the Huffman code to represent a symbol. In some  
13 cases the calculation might have to be done over several combinations of symbols.

14

15 It is also noted that various aspects of the present invention are shown herein in a  
16 single preferred embodiment. Other alternative embodiments could use one but not  
17 all aspects of the present invention. For example the part of the present invention  
18 that relates to maintaining bit rate could be used in embodiments which do not use  
19 macro blocks to establish an orientation grid. Likewise the aspect of the present  
20 invention which relates to the use of macro blocks could be used without the part of  
21 the invention that relates to maintaining a constant bit rate. Finally, while the  
22 invention has been shown in an embodiment that inserts a watermark in the DCT  
23 domain, the invention could be used in applications where watermarks are inserted  
24 in other domains.

25

26 While the invention has been shown and described with respect to preferred  
27 embodiments of the invention, various changes in form and detail could be made

- 1 without departing from the spirit and scope of the invention. The applicant's
- 2 invention is limited only by the appended claims.

I claim:

1. A method for adding a multibit watermark to an image comprising,  
generating DCT (Discrete Cosine Transform) coefficients representing said image,  
said coefficients being arranged in blocks, said blocks being arranged into  
macro blocks,  
adjusting said coefficients in accordance with the bits of said watermark to embed  
said watermark in said image, said adjustments being made in a direction  
that sinusoids generated by said adjustments are in phase across block  
boundaries in each macro block.

2. The method of claim 1 wherein each of said macro blocks contains four blocks.

3. The method of claim 2 wherein the blocks in each macro block are numbered  
one, two, three and four and wherein the coefficients in each block are arranged in  
rows and columns, alternate of said rows and columns being designated even and  
odd rows and columns,  
the coefficient in block one being changed directly in response to the bits of said  
watermark, the bits in blocks two, three and four being changed in accordance with  
the following rules:

Block 2: invert the direction of the change if the coefficient is in an odd row.

Block 3: invert the direction of the change if the coefficient is in an odd

column

Block 4: invert the direction of the change if the coefficient is in an odd row

or if it is in an odd column, but do not invert the direction of the

change if the coefficient is in both an odd row and in an odd column.



1  
2 4. A system for adding a multibit watermark to an image comprising,  
3 means for generating DCT (Discrete Cosine Transform) coefficients representing  
4 said image, said coefficients being arranged in blocks, said blocks being  
5 arranged into macro blocks,  
6 means for adjusting said coefficients in accordance with the bits of said watermark  
7 to embed said watermark in said image, said adjustments being made in a  
8 direction that sinusoids generated by said adjustments are in phase across  
9 block boundaries in each macro block,  
10 whereby the same changes which represent said watermark form a grid which can  
11 be used to detect the scale and rotation of said watermark.

12  
13 5. The system of claim 4 wherein each of said macro blocks contains four blocks.

14  
15 6. The system of claim 5 wherein the blocks in each macro block are numbered  
16 one, two, three and four and wherein the coefficients in block are in rows and  
17 columns, alternate of said rows and columns being designated even and odd rows  
18 and columns,

19 The coefficient in block one being changed directly in response to the bits of said  
20 watermark, the bits in blocks two, three and four being changed in accordance with  
21 the following rules:

22 Block 2: invert the direction of the change if the coefficient is in an odd row.

23 Block 3: invert the direction of the change if the coefficient is in an odd  
24 column

25 Block 4: invert the direction of the change if the coefficient is in an odd row  
26 or if it is in an odd column, but do not invert the direction of the  
27 change if the coefficient is in both an odd row and in an odd column.

1

2 6. A method of embedding a watermark into an image comprising,  
3 dividing the elements which form said image into blocks and arranging said blocks  
4 into macro blocks,  
5 introducing said watermark into the blocks in each macro block in an orientation  
6 such that the resulting sinusoids are in phase across block boundaries in each  
7 macro block,  
8 whereby said watermark can be used to both carry data and form a grid which can  
9 be detected to show orientation of said watermark.

10

11 7. A method of introducing a watermark into a stream of bits representing variable  
12 length codes without changing the bit rate of said stream of bits comprising,  
13 maintaining a cumulative change amount which indicates the amount of the positive  
14 and negative changes which are made to said codes,  
15 suspending any positive changes if the cumulative change amount exceeds a pre-  
16 established limit,  
17 whereby the bit rate of said stream of bits is maintained constant.

18

19 8. A system for introducing a watermark into a stream of bits representing variable  
20 length codes without changing the bit rate of said stream of bits comprising,  
21 means for maintaining a count of the amount of positive and negative changes  
22 which are made to said codes,  
23 means for suspending any positive changes if a pre-established limit is exceeded,  
24 whereby the bit rate of said stream of bits is maintained constant.

25

26

1 9. A method for adding a multibit watermark to an image comprising,  
2 generating DCT (Discrete Cosine Transform) coefficients representing said image,  
3 said coefficients being arranged in blocks, said blocks being arranged into  
4 macro blocks,  
5 adjusting said coefficients in accordance with the bits of said watermark to embed  
6 said watermark in said image, said adjustments being made in a direction that  
7 sinusoids generated by said adjustments are in phase across block boundaries in  
8 each macro block.  
9 maintaining a cumulative change count of the positive and negative changes which  
10 are made to said codes,  
11 suspending any positive changes if said cumulative change count exceeds a pre-  
12 established,  
13 whereby said watermark forms a grid which can be detected to determine  
14 orientation and scale of said watermark and the bit rate of said stream of bits is  
15 maintained constant.

16  
17 10. An image processing method that includes steganographically encoding an  
18 input image to embed a multi-bit code therein,  
19 generating DCT (Discrete Cosine Transform) coefficients representing said image,  
20 said coefficients being arranged into primary size blocks,  
21 arranging said DCT coefficients into macro blocks, each containing four of said  
22 primary size blocks,  
23 changing the coefficients in each block to encode therein a watermark in said  
24 image,  
25 the direction of change of said coefficients being such that the sinusoids created by  
26 said changes are continuous across the primary blocks in said macro blocks,

1 whereby said watermark signals can be used to both carry data and to form an  
2 orientation and calibration grid.

3

4 11. The method recited in claim 10 wherein said primary blocks each contain 64  
5 DCT coefficients and each macro blocks contains four of said primary blocks.

6

7 12. The method of claim 7 wherein  
8 negative changes are suspended if the cumulative change amount exceeds a pre-  
9 established negative amount.

10

11 13. The system of claim 8 including  
12 means for suspending any negative changes if said count exceeds a pre-  
13 established negative limit.

14

15 14. The method of claim 9 wherein  
16 negative changes are suspended if said cumulative change count exceeds a pre-  
17 established negative limit.

18

19 15. A method of embedding a watermark in a stream of coded symbols that  
20 represent a series of images by selectively increasing or decreasing the values  
21 of said symbols, said method comprising,  
22 establishing a limit on the allowable entropy of said stream of bits,  
23 suspending said selective increasing if said limit is exceeded.

1

2 16. A method of embedding a watermark in a series of bit which represent an  
3 image without increasing the entropy of said image beyond a pre established  
4 limit, comprising the steps of:  
5 changing selective bits of said image to embed said watermark,  
6 maintaining a cumulative change count of the changes made to embed said  
7 watermark in said image,  
8 suspending changes which cause said cumulative change count to exceed a pre  
9 established limit.

10

11 17. A method of embedding a watermark in a series of bit which represent an  
12 image without increasing the entropy of said image beyond a pre established  
13 limit comprising the steps of:  
14 maintaining a count which represents the change in entropy as said watermark is  
15 being embedded in said image,  
16 suspending changes in said image when said count is beyond a specified limit.

17

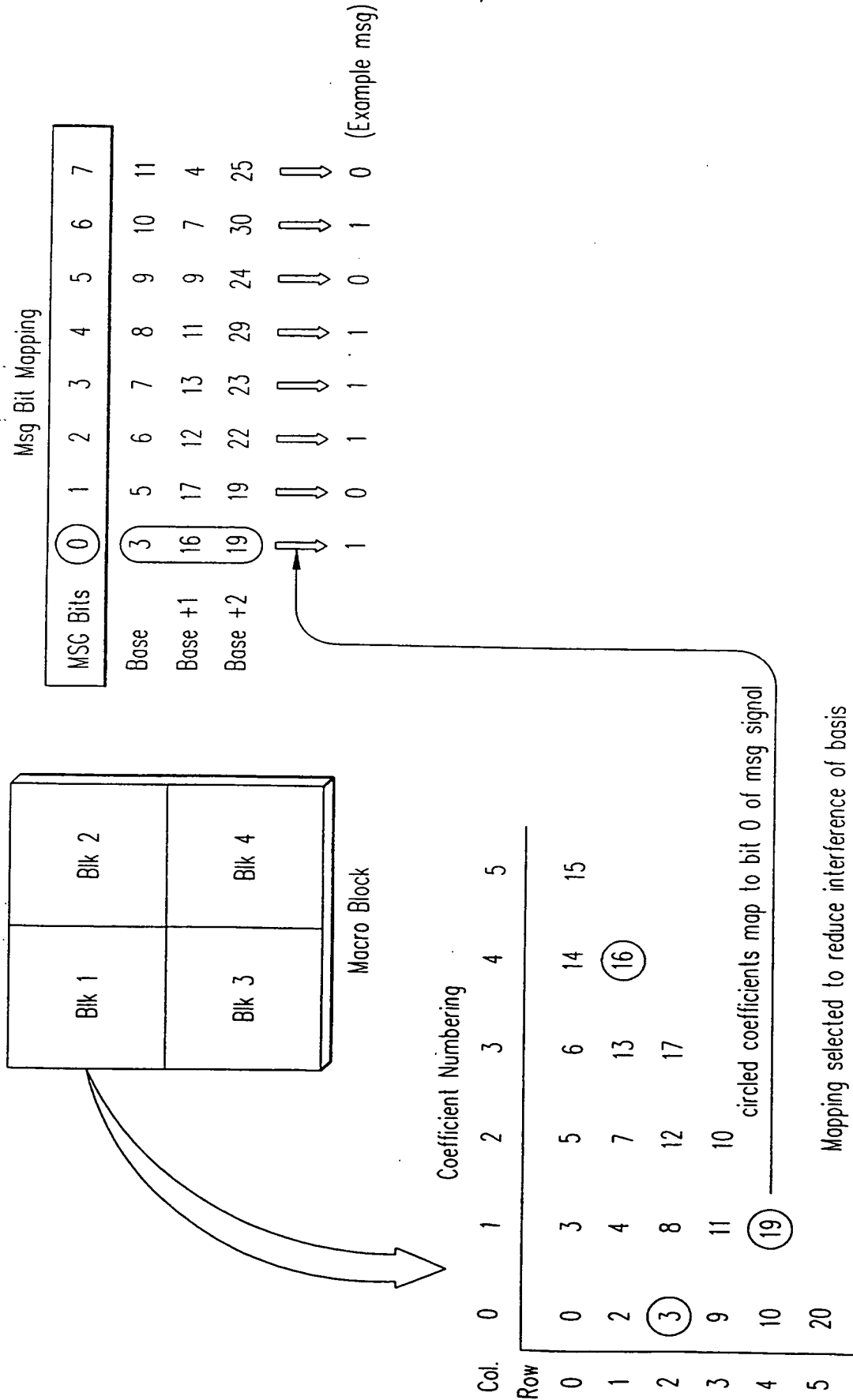
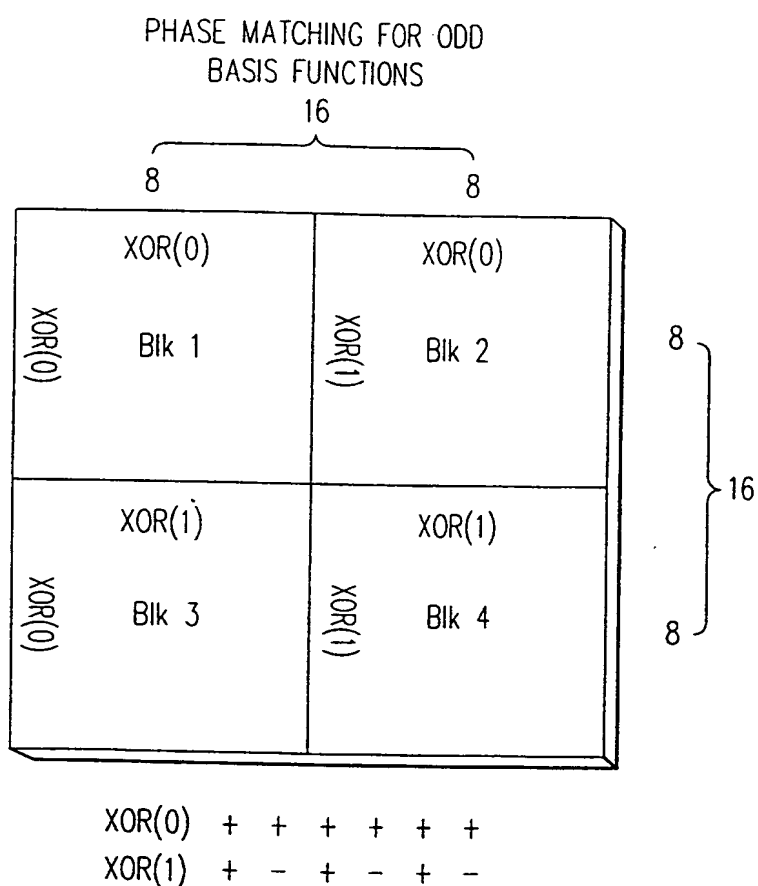


FIG. 1

Mapping selected to reduce interference of basis functions, and so probability of any grouping of them being non-zero is the same for all bits.

**FIG. 2**

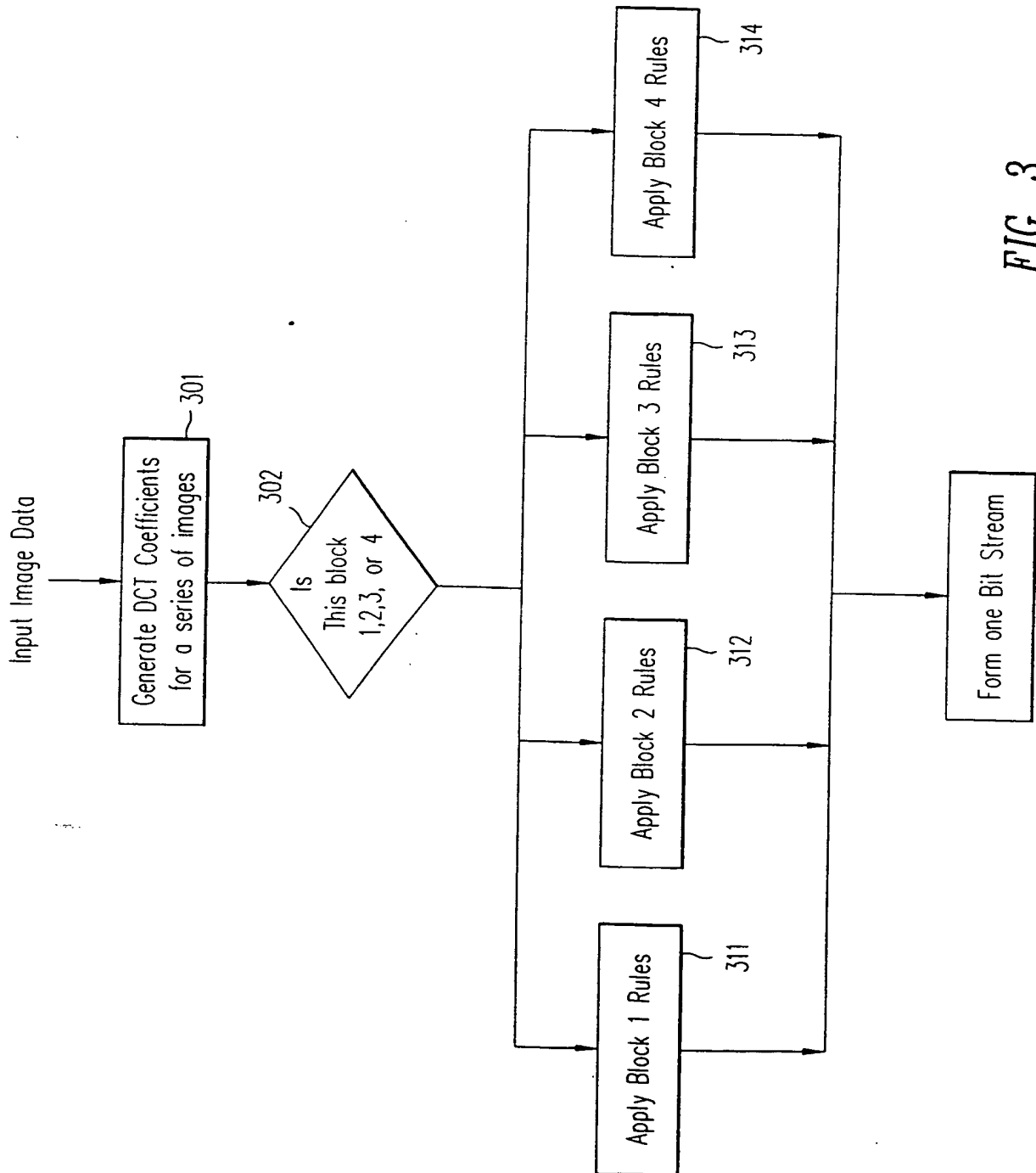


FIG. 3



4/4

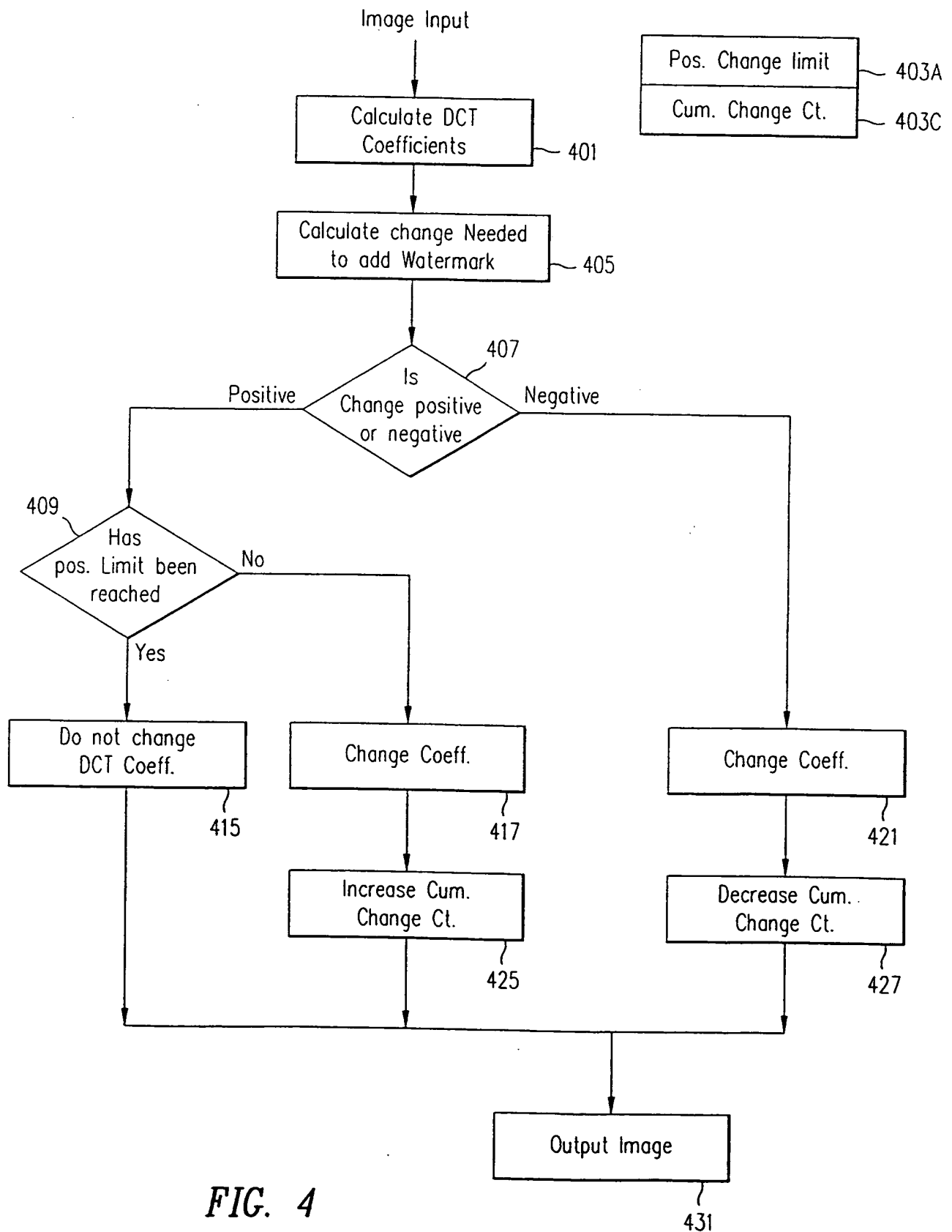


FIG. 4

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US98/17530

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : G06K 9/36, 9/46

US CL : 382/232, 250; 380/5, 20

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 382/232, 250, 100; 380/5, 20, 23, 49

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A,E	US 5,809,139 A (GIROD et al) 15 September 1998.	1-17

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
*A* document defining the general state of the art which is not considered to be of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
*E* earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
*L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*A* document member of the same patent family
*U* document referring to an oral disclosure, use, exhibition or other means	
*P* document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

07 DECEMBER 1998

Date of mailing of the international search report

14 JAN 1999

Name and mailing address of the ISA/US  
Commissioner of Patents and Trademarks  
Box PCT  
Washington, D.C. 20231

Facsimile No. (703) 305-3230

Authorized officer

PHUOC TRAN

Telephone No. (703) 305-3900

Joni Hill